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DEPOSITIONAL SYSTEMS IN THE RINCONADA FORMATION (PRECAMBRIAN), TAOS COUNTY NEW MEXICO

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INTRODUCTION

The Rinconada Formation is part of a metasedimentary sequence exposed in the Picuris Range south of Taos, New Mexico. It is composed of interbedded quartzite and schist, which has been metamorphosed to medium grade and undergone successive deformations. In spite of this, the quartzite units still retain many sedimentary textures, including abundant crossbeds, and original vertical and lateral variations in grain size. Analysis of the sedimentary features has resulted in the recognition of several depositional environments within the Rinconada.

METHODS OF STUDY

Measured sections were made at the 12 locations shown in Figure 1. Of these, five contain the entire section. Paleocurrent

measurements were made on tabular and trough crossbeds, and structural information about the outcrops was recorded. The paleocurrent data then were plotted on stereonet and the structural influences removed. The resulting data are presented as rose diagrams.

The Picuris Range is dominated by two large, isoclinal folds, the Hondo syncline and the Copper Hill anticline (Montgomery, 1953). Because the folds are isoclinal, one would expect that passive folding would have been the dominant mechanism and that the present thickness of the Rinconada would be controlled structurally.

Analysis of the degree of dip of the crossbeds shows that regardless of position on a fold, the shear within the quartzite units of the Rinconada is negligible and that the direction of dip is a reliable indicator of sediment transport direction. Because the quartzite was deformed concentrically, it is at or near its original thickness. The thickness of the schist, on the other hand, may have changed dramatically to fill space created during folding, and consequently, the total measured

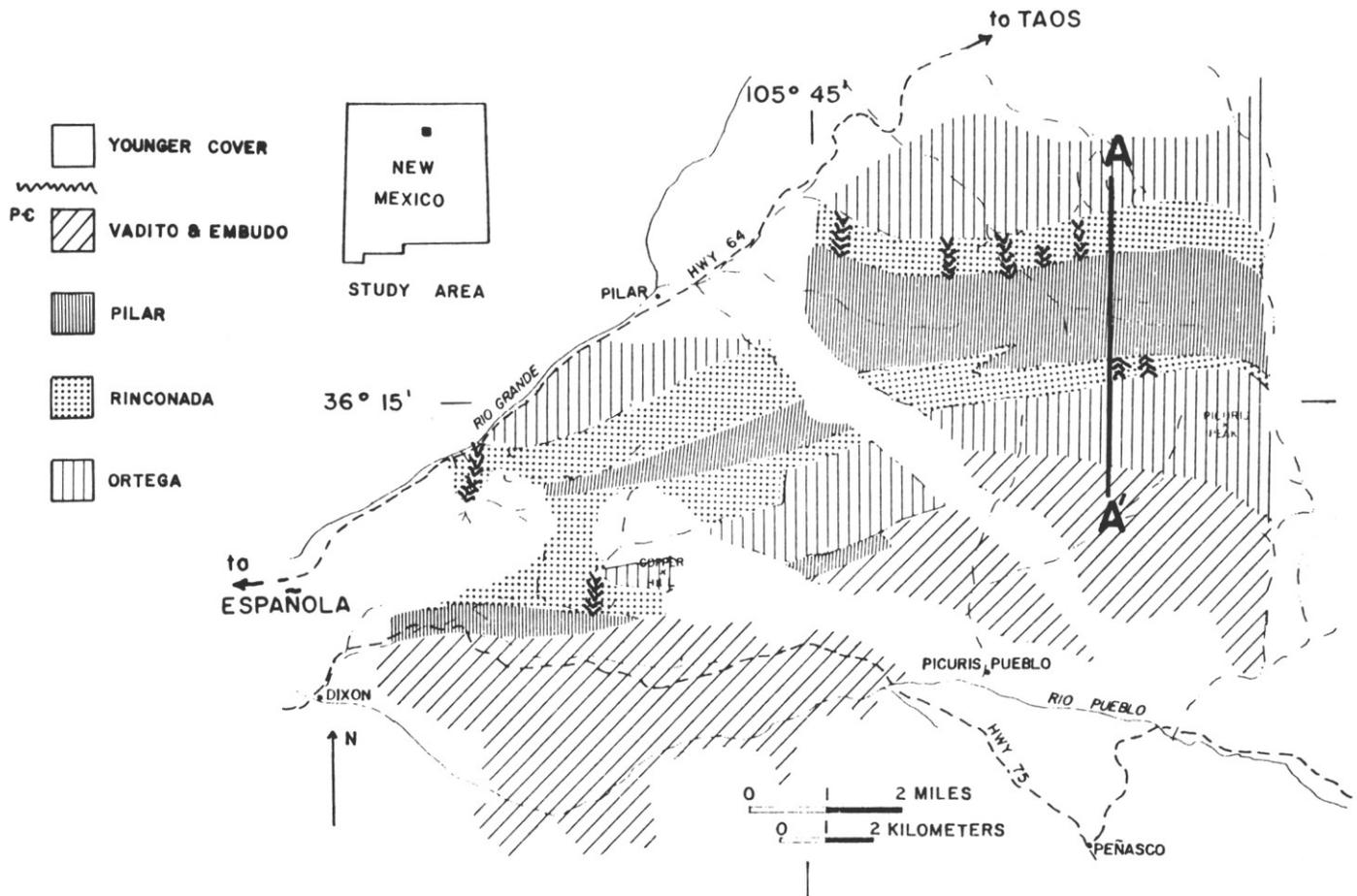


Figure 1. Generalized geologic map of part of the Picuris Range (after Montgomery, 1953; Nielsen, 1972). Locations of measured sections shown in chevron pattern. A-A' is location of cross section in Figure 4.

thickness of the formation may be quite different than the original depositional thickness.

PREVIOUS WORK

Just (1937) published the first reconnaissance of the Picuris Range. His work was expanded upon by Montgomery (1953), who produced a remarkably accurate map of the area. This information was presented later in slightly altered form as part of a larger study by Miller and others (1963). Nielsen (1972), and Nielsen and Scott (this guidebook) worked out much of the structural evolution of the range. Brookins (1974) published a summary of the Rb-Sr ages for the Precambrian rocks of this area, and Gresens and Stensrud (1974) presented evidence for the existence of metarhyolite in the Picuris. HoIdaway (1978) analyzed the metamorphic mineral assemblages.

PRESERVATION OF SEDIMENTARY TEXTURES

The interpretation of depositional systems in a metasedimentary sequence requires the preservation of sedimentary structures, and the original vertical and lateral variations in grain size. Several types of sedimentary structures have been preserved in the quartzite of the Rinconada, including crossbeds (fig. 2), ripple marks and graded bedding. In addition, metasomatism does not appear to have played a large role in the metamorphism of the Rinconada, so that the present abundance of quartz in individual beds is clearly a product of the composition of the original sediment.

Bingler (1965) contended that features interpreted as crossbeds in the highly deformed Ortega Quartzite in the La Madera quadrangle are actually tectonic textures, and some of the outcrops in his area support his belief. However, Barker (1958), Doney (1968) and Muehlberger (1967) discussed Ortega outcrops of greenschist or amphibolite facies to the northwest of Bingler's area, which contain pebble beds, crossbeds and other features which are readily identifiable as sedimentary.

RINCONADA STRATIGRAPHY

Introduction

The oldest unit exposed in the Picuris Range is the Ortega Quartzite, which is in excess of 800 m thick. It is overlain by the Rinconada Formation, which for the purpose of this

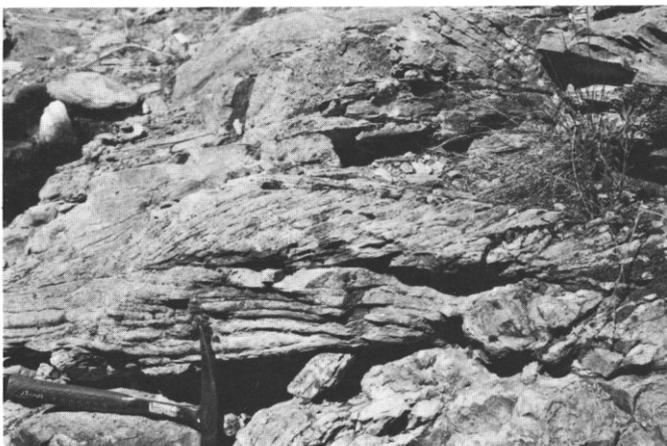


Figure 2. Crossbeds in quartzite in the Copper Hill area (R_3 of Nielsen, 1972).

study, has been divided into four members. Above the Rinconada is the slate and phyllite of the Pilar Formation. Lying above the Pilar is metaconglomerate, amphibolite and schist of the Vadito Formation. These rocks were intruded locally by the Embudo Granite which was emplaced 1.67 billion years ago (Fullagar and Shiver, 1973). Except for the division of the Rinconada into four members, this stratigraphic terminology is the same used by Nielsen (1972) (modified from Montgomery, 1953).

Northern Exposures

The Rinconada Formation crops out in two bands which trend east-west through the main part of the Picuris Range; in addition, it has broad areas of outcrop in the southwestern portion of the range where it swings around the crest of the Copper Hill anticline. Because of the many differences that exist between the northern exposures and those on the southern limb of the Hondo syncline and in the Copper Hill area, it is best to discuss the two areas separately.

The Rinconada exposed on the northern limb of the Hondo syncline is nearly 700 m thick and is divisible into four members: a basal schist, a staurolite schist, an interbedded quartzite and schist, and a phyllite.

The basal member is an extremely coarse-grained muscovite-andalusite-biotite schist, which is about 80 m thick. The andalusite is poikiloblastic and forms knots (knotenschiefer) that are up to 30 cm in diameter. The knots are not as prominent in the highest part of this member where it grades into the overlying staurolite schist. This rock is the andalusite-biotite hornfels of Montgomery (1953) and is equivalent to the R_1 of Nielsen (1972).

The second member is a muscovite-staurolite-garnet-biotite schist, which is 50-120 m thick. It is recognized easily in the field due to the occurrence of large, twinned staurolite crystals which stand out in relief on weathered surfaces. Near the top of this member, cordierite locally becomes an important constituent and may make up more than half of the rock.

The interval of interbedded quartzite and schist is 350-450 m thick and begins 130-200 m above the contact with the Ortega. Within this interval, the number, thickness and geometry of the quartzite units are highly variable. The top of this member is marked by a 50-85-m-thick quartzite which is equivalent to the R_s of Nielsen (1972). Within this member, there is a transition from quartzite units which coarsen upward to quartzite units which have sharp bases and fine upward.

These upward-coarsening sequences can be divided into two parts: (1) a lower section of interbedded quartzite and schist 5-15 m thick, and (2) an upper section of nearly pure quartzite of about the same thickness. The number of upward-coarsening sequences increases to the west, where as many as three or four such intervals exist in the section exposed along the Rio Grande south of Pilar. Sedimentary structures are not preserved well in these sequences.

These upward-coarsening sequences are interpreted to be the product of deltaic progradation. The fine-grained sediments at the base of the Rinconada are shelf and prodelta deposits, while the alternating quartzite and schist sections were deposited in a distal delta environment. The clean quartzite capping each sequence is interpreted to be delta front sand. Quartzite intervals only 1-2 m thick lying above these sequences may have originated by marine reworking of the deltaic sand into strandplains.

Higher in the section, the quartzite occurs in upward-fining sequences which are 7-17 m thick. Commonly, the lowest part of each sequence is uniformly coarse-grained, with only the upper 5 m showing the upward-fining trend. Large-scale trough crossbeds are common in the lower part of each sequence, but tend to decrease in size and abundance upward. In the fine-grained parts, horizontal laminations are the most common sedimentary structure. On the basis of their grain size trends and associated sedimentary structures, these sequences are interpreted to have formed as channel and point-bar deposits.

The uppermost member of the Rinconada is a muscovite-biotite-garnet phyllite, which is 50-75 m thick and is equivalent to the R6 of Nielsen (1972). In the field, it is recognized easily by its crinkled appearance. The contact with the underlying member is sharp, and its texture and mineralogy are uniform throughout. The contact with the Pilar Formation is marked by a dark blue to black garnetiferous quartzite.

Southern Exposures

In the southern exposures, the Rinconada is only about 400 m thick, but the four members defined in the northern part of the range can be recognized with only minor variations. The main differences occur in the basal member and in the quartzite sequences which make up the quartzite and schist member.

The greatest lithologic difference between the northern and southern exposures occurs in the basal member. In the south, it is a muscovite-biotite schist, which is about 35 m thick. It is fine-grained and has a salt-and-pepper appearance in the field. Near the contact with the Ortega, there are knots composed mostly of chlorite and sericite. The textures of these knots suggest that an original assemblage of andalusite and biotite underwent retrograde metamorphism.

The overlying member is a muscovite-staurolite-garnet-biotite schist and is equivalent to the R2 of Nielsen (1972). The bottom contact is very sharp and is marked by a bluish quartzite bed about 1 m thick. At the top of this member, the schist is quartz-rich and staurolite is less abundant.

The interbedded schist and quartzite member in the Copper Hill area consists of two thick quartzites separated by a muscovite-garnet-biotite schist. Nielsen (1972) defined three members, R3-R5, in this interval. The basal quartzite is about 60 m thick and is composed of interbedded blue and tan quartzite. The blue quartzite occurs as lenses which truncate the underlying beds. The width of these lenses varies from less than 1 m near the base to as much as 5 m higher in the section. Above the lenses, the quartzite fines upward over an interval of about 2 m until another blue lens is reached.

Crossbeds are abundant throughout this interval. The tan beds most commonly contain tabular crossbeds, while the blue intervals contain trough crossbeds almost exclusively. A rose-diagram plot of the sediment transport directions shows a prominent bimodal, bipolar trend. Higher in the section, the quartzite becomes cleaner, and plane beds and very low-angle tabular crossbeds occur.

The lowest part of this interval almost certainly was deposited in a tidal-flat environment. The blue lenses probably represent tidal-channel deposits. According to Klein (1971), the mean thickness of the upward-fining sequences is equivalent to the paleotidal range, about 1-2 m. The upper part of this quartzite interval probably formed in a beach or barrier-island environment.

The upper quartzite in the Copper Hill area has many simi-

larities to the deltaic deposits described from the northern exposures, and probably represents delta-front deposits. To the east, the two quartzites merge and are entirely of shallow-marine origin.

The uppermost member is a muscovite-biotite-garnet phyllite, which is 60-90 m thick. It is identical to the phyllite member described in the northern exposures.

HOLOCENE EQUIVALENTS

There are many difficulties inherent in comparing Precambrian sediments with recent; however, there are many similarities between the facies discussed here and descriptions of Holocene examples.

The distribution of sand in ancient deltas is the most important clue in developing a model for their formation. Because of the structural complexity of the Picuris Range, it is impossible to ascertain the original sand distribution with any confidence. In many of the outcrops, the deltaic sand appears to have been reworked by marine processes, so that it is likely that these deltas were of the wave-dominated type. They may have been similar to the Po delta, Gulf of Venice, as described by Fisher and others (1969).

Fluvial deposits in the Rinconada appear very similar to those described by Williams and Rust (1969) from the Donjek River, a braided stream in the Yukon, Canada. Both the vertical grain-size trends and associated sedimentary structures are nearly identical in the two cases.

Tidal-flat deposits described by Oomkens (1974) from the Niger delta system are similar to those found in the lower quartzite in the Copper Hill area. The regressive phase includes a facies tract which corresponds well with the tidal-flat-shoreface sequence in the Precambrian sediments.

PALEOCURRENT DATA

Paleocurrent data were collected from outcrops at the locations shown in Figure 3. The orientations of all crossbeds which could be seen in three dimensions were recorded. All readings are believed to be from a stratigraphic level equivalent to the lower quartzite in the Copper Hill area.

Three prominent trends can be observed: southerly, westerly and bimodal northwest-southeast. The measurements from the northern limb of the Hondo syncline were made in intervals interpreted as being fluvial deposits and show a strong southerly trend with a subordinate westerly component. The outcrop which gives the bimodal plot from the Copper Hill area is part of the sequence interpreted as tidal-flat deposits. The two plots with a strong westerly component were made from outcrops which represent shallow-marine facies, and which probably were deposited by longshore currents.

BASIN GEOMETRY

The thickness of the Rinconada changes dramatically in just a few kilometers, thinning from 700 m on the northern limb of the Hondo syncline to about 400 m on the southern limb. Although there are many possible explanations for this variation, there are good reasons to believe that it represents a difference in depositional thickness.

Even if gross changes in the thickness of the schist occurred during deformation, the quartzite likely is near its original thickness. The total thickness of all quartzite in the northern exposures is 200-300 m, where it comprises 35-50% of the

PALEOCURRENT MEASUREMENT LOCATIONS

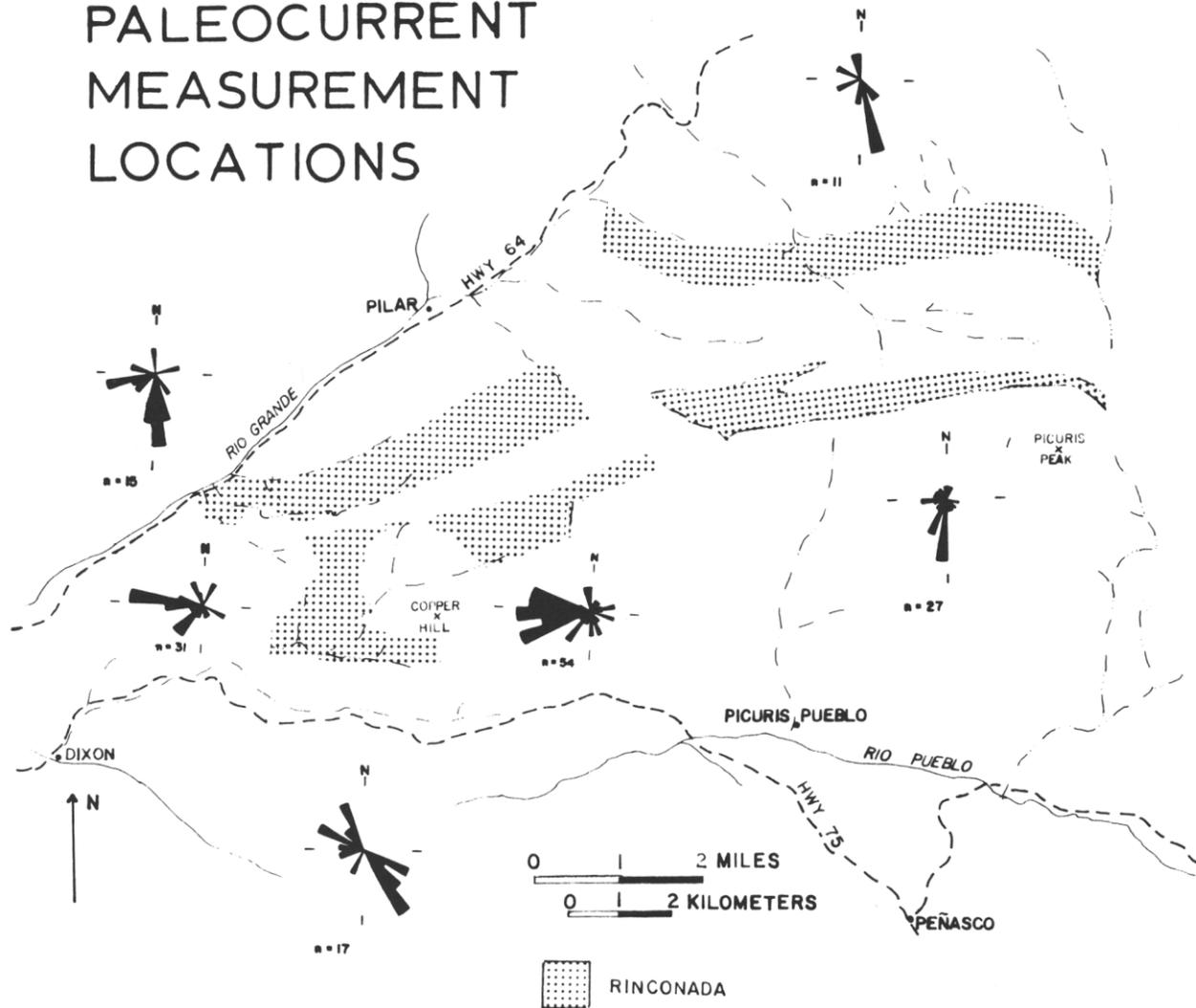


Figure 3. Paleocurrent rose diagrams and outcrop locations.

stratigraphic section. In the south, it is only 85-135 m thick, and makes up just 20-35% of the section.

The facies represented by the quartzite intervals contrast in the two areas. In the north, the quartzites constitute a regressive sequence, beginning with several episodes of deltaic progradation and culminating in a thick fluvial section; in the south, only one deltaic sequence can be recognized and most sediments appear to be of beach and shallow-marine origin.

Figure 4a shows a generalized north-south cross section through the Hondo syncline. If the fold is removed and the top of the Rinconada is restored to horizontal, then the geometry in Figure 4b results.

PETROGRAPHY

Relict sedimentary textures can be observed in a few thin sections of the quartzite beds. These textures include original grain boundaries and detrital heavy minerals.

In a sample taken from the quartzite at the contact between the Rinconada and Pilar formations, identification of original grain size is possible even though the quartz has been recrystallized completely. In thin section, elliptical shapes are defined by a combination of magnetite (or ilmenite), plagioclase and garnet. The elliptical shapes probably represent flattened

detrital quartz grains in an iron-rich clay matrix, which when metamorphosed, produced the assemblage of quartz, magnetite, plagioclase and garnet. Much of the plagioclase has been altered to sericite. The abundance and distribution of the magnetite suggest that it was not a detrital mineral but was present in the interstitial clay. The elliptical shapes reveal that the original grains were approximately 1 mm in diameter.

A thin section of one of the tan friable quartzites from the Copper Hill area is rich in detrital tourmaline. Many, but not all, of the tourmalines contain well rounded cores which are pleochroic from dark blue to colorless (fig. 5). They are covered by overgrowths which have irregular outer boundaries and are pleochroic from light green to nearly colorless, the same colors seen in the tourmalines from the schist units. The average size of the detrital nucleus is about 0.15 mm, or fine-sand size. Because of the density of tourmaline, it would tend to travel with quartz grains about 0.50 larger (Folk, 1974), so the original grain size of the sediment was probably near the boundary between fine and medium sand.

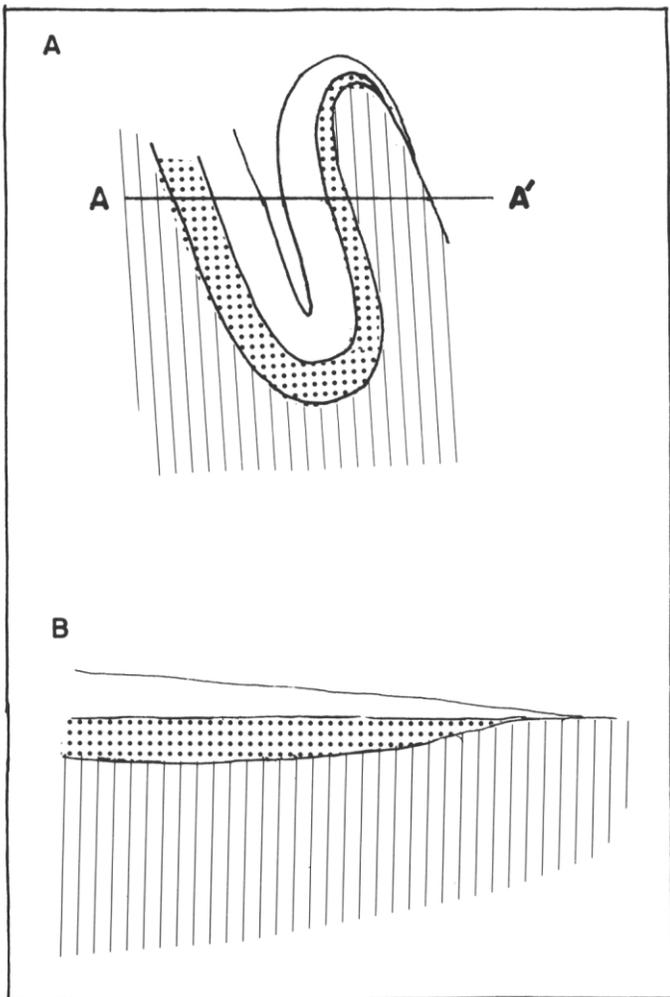


Figure 4. (A) Generalized cross section at location shown on Figure 1. (B) Cross section with the top of the Rinconada restored to horizontal.

DEPOSITIONAL HISTORY

The Rinconada Formation was deposited as interbedded sand and mud in deltaic, fluvial and shallow-marine environments. These sediments were derived from the north and accumulated in a trough that paralleled the coast.

Metamorphism has erased all of the sedimentary features from the basal schist and staurolite schist members. However, they are overlain by deltaic sediments so that they probably were deposited as shelf and slope muds. The profound lithological differences between the Ortega and the two lowest members of the Rinconada might have been caused by a major transgression.

The quartzite and schist member is a regressive sequence in the north, but to the south, it appears to be entirely shallow-marine and deltaic. In the northern exposures, the lower quartzites are deltaic and were deposited in distal-delta and delta-front environments; the interbedded schist probably consists of delta-plain or shelf deposits. The distinctive differences of the fine-grained deposits have been destroyed.

Fluvial systems prograded over the area, depositing sand in point bars and channels. These fluvial systems were fairly coarse-grained and probably of rather low sinuosity. Their deposits are laterally more persistent higher in the section and

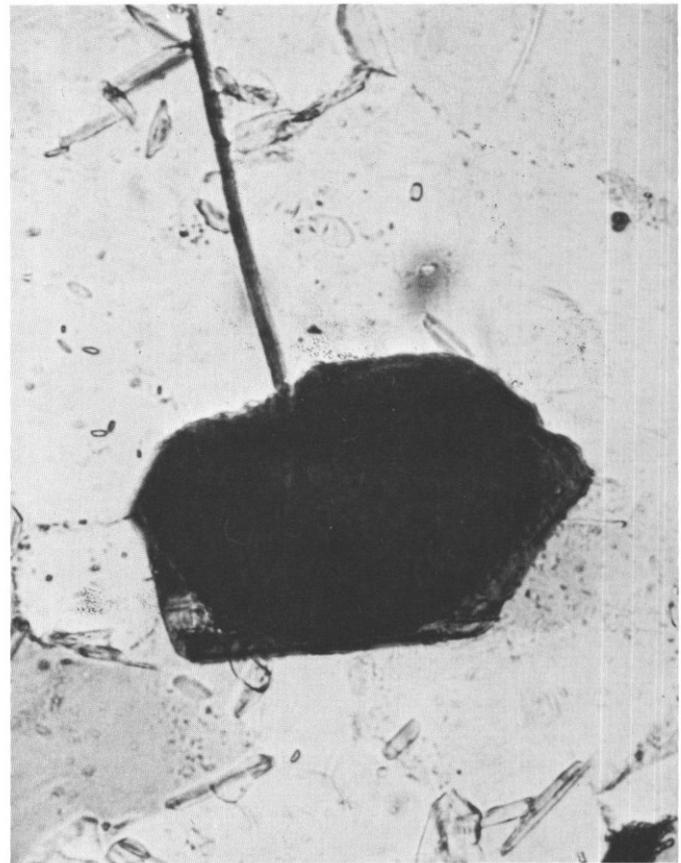


Figure 5. Photomicrograph of a tourmaline from a tan quartzite (R_3 of Nielsen, 1972) in the Copper Hill area. Long dimension of the tourmaline is 0.2 mm.

consequently, were probably better integrated. The rivers provided sediment for shallow-marine and deltaic deposits to the south. The shallow-marine facies include tidal flat, beach and offshore bar. Figure 6 is a schematic reconstruction of how the area may have looked during deposition.

The phyllite member represents an abrupt return to fine-grained sedimentation throughout the area. It is overlain by the Pilar Slate, which may be deep-water or starved-basin deposits. This implies that the quartzite which marks the contact between the Rinconada and Pilar formations is transgressive.

The greater thickness of the Rinconada in the north is attributable largely to the greater thicknesses of the lower members and the deltaic sequences, which are missing to the south. While deltaic sedimentation was active in the north, the southern area was receiving little sediment. Eventually, shallow-marine sedimentation commenced in the south. The thickness of the phyllite member is the same at all points in the area, indicating that differential subsidence between the two areas had ceased prior to its deposition. The upward termination of the inferred growth fault at the phyllite level in Figure 6 marks the end of the differential subsidence.

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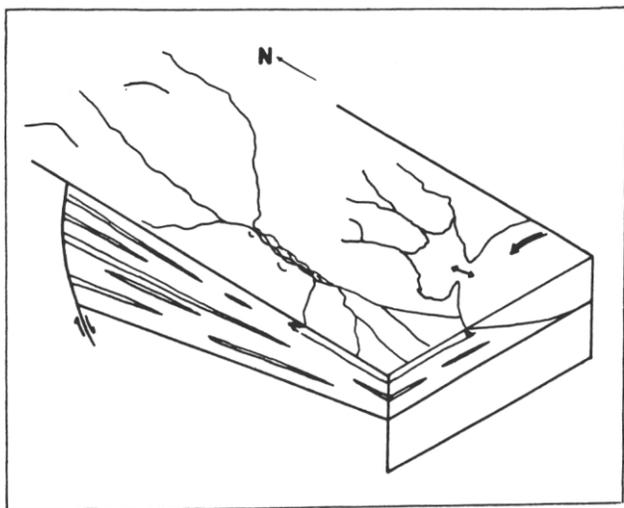


Figure 6. Paleogeographic reconstruction of the Rinconada prior to deposition of the sediments which formed the uppermost unit, the phyllite member or R_6 of Nielsen (1972).

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